

# Reverse Skew-T – A Cloudmaking Tool for CG

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## Abstract

*We present ‘Reverse Skew-T’, a tool that allows users to direct a physically inspired simulation of layered clouds. To achieve this, we extend existing models for cloud simulation and provide a graphical user interface for providing important simulation parameters to our system.*

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation; I.6.8 [Simulation and Modeling]: Types of Simulation—Visual

## 1. Introduction

Clouds in the sky are an important aspect of natural outdoor scenes. Pure physically based cloud simulations, however, are notoriously difficult to control. The challenge then is for any solution to be computationally lightweight and able to be user directed in some measure while at the same time producing believable visual results.

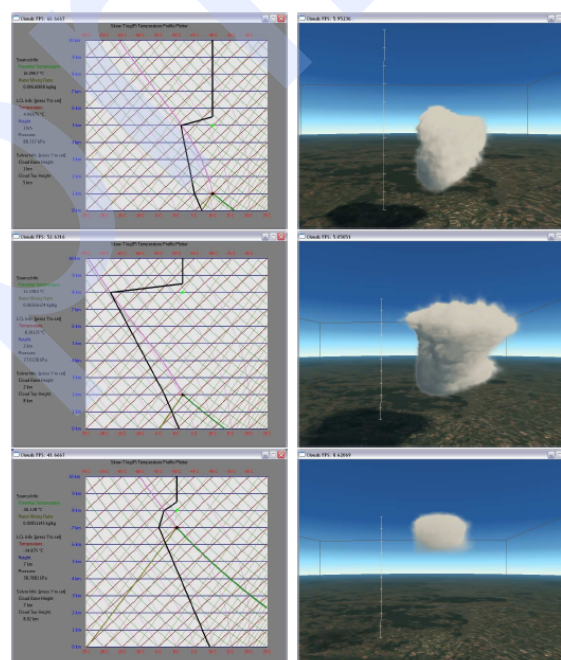
## 2. Background

There exist a number of physically-based approaches for cloud simulation [MDN02, HBSL03], for which improvements have mostly focused on the fluid dynamics solution while the cloud physics model has largely remained unchanged. Most works incorporate the thermodynamic effects of phase transitions and assume that the atmospheric temperature falls with height according to a fixed lapse rate.

A certain amount of user direction for cloud control has been presented by Dobashi et al. [DKNY08], where users determine a desired shape for the cloud height and then their system adjusts the latent heat release and vapour levels to force the cloud into this shape. This technique is able to achieve a relatively fine level of control and could complement our work.

## 3. Directable Cloud Simulation

Existing cloud simulation solutions in computer graphics employ a fixed-rate for the simulation’s background-atmospheric temperature profile. Our inclusion of an arbitrary temperature profile can lead to more visually inter-



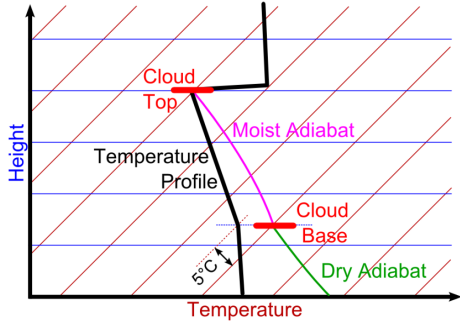
**Figure 1:** Using our ‘Reverse Skew-T’ tool to adjust the temperature profile (left) to give a cloud formation (right).

esting and controllable results. To achieve this, our cloud physics model uses the following equation adapted from

Rogers and Yau [RY89]:

$$F_B = \mathbf{g}B = \mathbf{g} \left( \frac{T}{T'} - (1+q) \right)$$

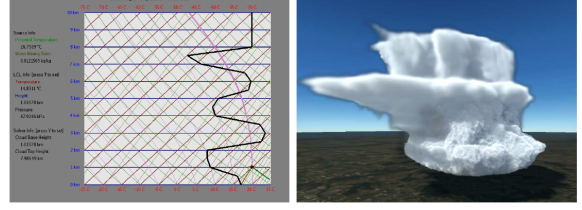
where  $\mathbf{g}$  is the gravitational acceleration vector,  $T$  is the atmospheric parcel temperature,  $T'$  is the ambient environment temperature taken from our background atmospheric description and  $q$  is the parcel's total mixing ratio of all condensates (all water categories except vapour).



**Figure 2:** Our ‘reverse’ skew-T tool. The user clicks for cloud base and cloud height, the tool automatically generates the background temperature profile and calculates the moisture and temperature seed levels required to produce this cloud.

Our work addresses the task of controlling the ambient environment temperature value  $T'$ . Whereas previous CG approaches have used a fixed function that defines  $T'$  as a function of height, i.e. the simulation’s ‘lapse-rate’, our system adds a level of directability by allowing users to define this vertical temperature profile manually. This use of a user defined function allows the cloud simulation to generate more varied results, including layered clouds (Figure 3). To simplify user input – the provision of a list of numbers is not intuitive and rather difficult to control or predict – some form of graphical user interface is needed.

Meteorologists use the *Skew-T log(P)* graph (commonly referred to as just a “skew-T”) thermodynamic chart [AWS90] to plot atmospheric profiles showing how temperature varies with height, i.e. to visually present this same data that users are meant to provide to our system. Inspired by this analysis tool we have developed the ‘Reverse Skew-T’ user interface (Figure 1) as a tool for specifying vertical temperature profiles for cloud simulation. Using the skew-T, specifying a cloud base and a cloud height becomes a relatively straight-forward problem for users of our system (Figure 2). From this, the atmospheric temperature profile and the required temperature and moisture of a source that will generate the desired cloud can be automatically determined by our system.



**Figure 3:** Layering effects achieved by manually adjusting the temperature profile with our tool. Cloud formation is enhanced in regions where the profile is to the left of the moist adiabat (the thick pink line in the Skew-T view), rising from the lifted condensation level (LCL – the point above which the cloud will start forming). Cloud formation is reduced in regions to the right of the curve. The example shown results in three layered regions, of which the mid-height one is the best defined.

#### 4. Discussion and Future Work

We have presented a cloud simulation user interface that allows users to visually define a background atmospheric description using temperature profiles that can be arbitrarily set and changed rather than being confined to a specific lapse-rate. The level of control that our system offers is a substantial improvement on previous work, allowing us to generate more varied results than are achievable with existing systems, but we believe that the control is still rudimentary and can be improved further, which we hope to address in the future.

#### References

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